Low-frequency shallow water reverberation and bottom scattering model

Fenghua Li, Jianjun Liu, Renhe Zhang

National Lab. Of Acoustics, IOA, CAS

Jixun Zhou

Georgia Tech

Supproted by NSFC and ONR

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
01 DEC 2002	**N/A**	**-**

4. TITLE AND SUBTITLE	
Low-Frequency Shallow Water Reverberation and Bottom Scattering Model	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **National Lab of Acoustics, IOA, CAS**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
Also See: M001452, The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**40**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Introduction

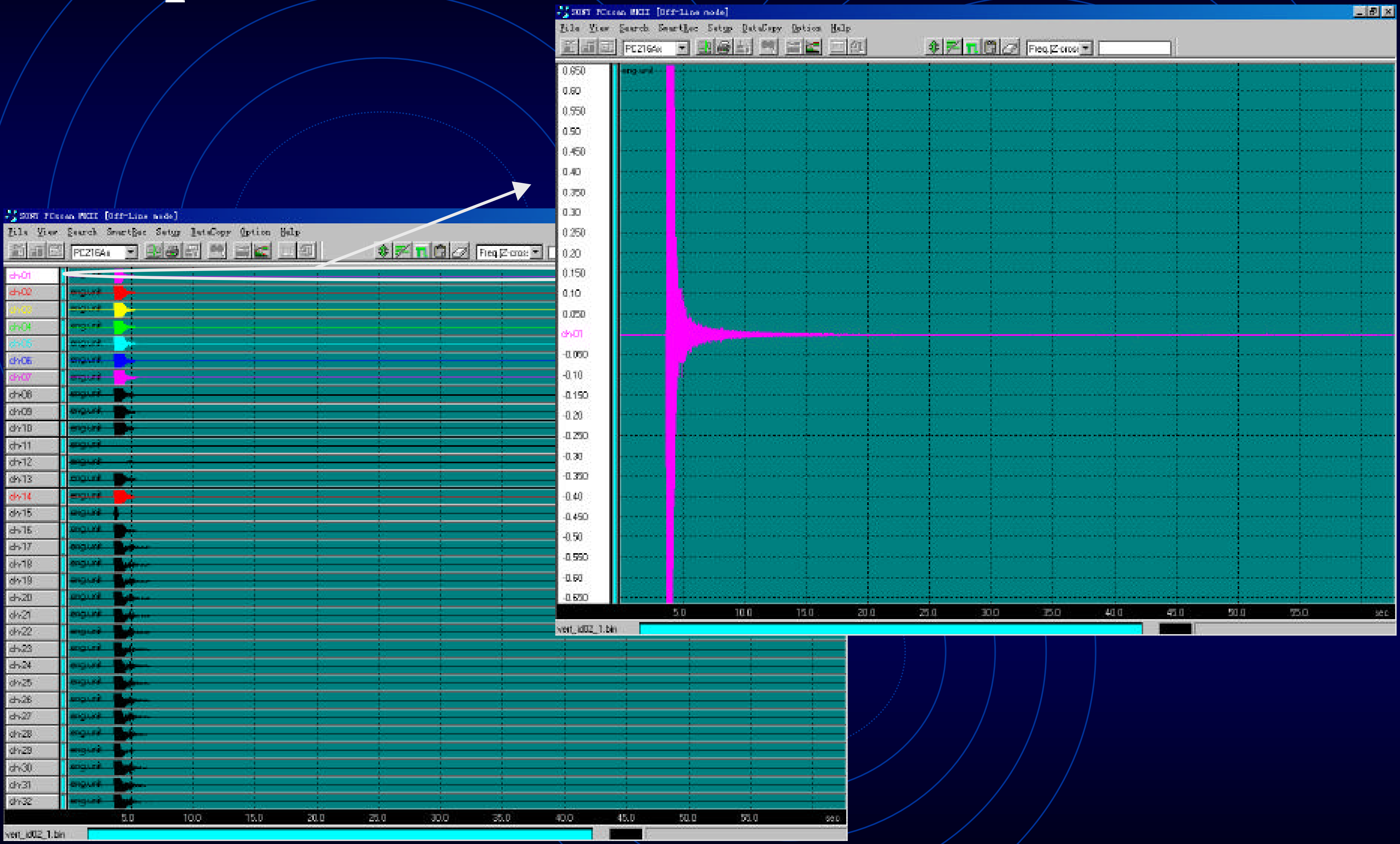
- The problems of reverberation model
  - Propagation model V
  - Bottom parameters ? V
  - Scattering model ?
    - Angle relationship
    - Frequency relationship
    - Physical mechanism
- Motivation of this talk
  - The ASIAEX01 reverberation data are used to validate different bottom scattering models.

Contents

- Middle frequency (700Hz to 2000Hz, in this report) reverberation loss to validate different bottom scattering models.
- Low frequency (<700Hz) reverberation loss and sediment-basement combined scattering model.

1. Middle Frequency reverberation data

Experimental Data



Data analysis procession

Recorded data $x(t)$

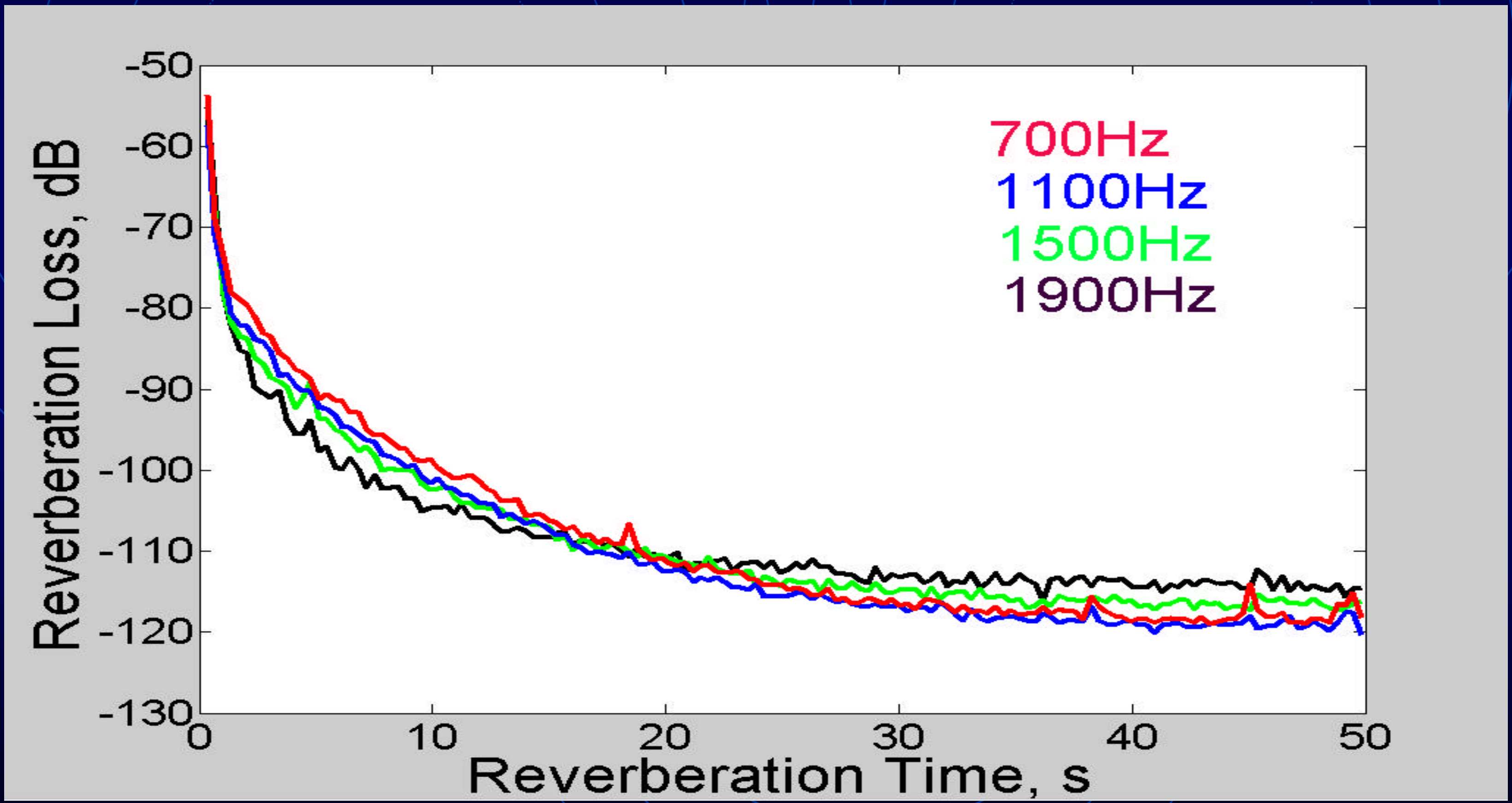
Narrow band filtering $y(t)=filter(x(t))$

Short time energy average $I(t0)=mean(y^2(t))$

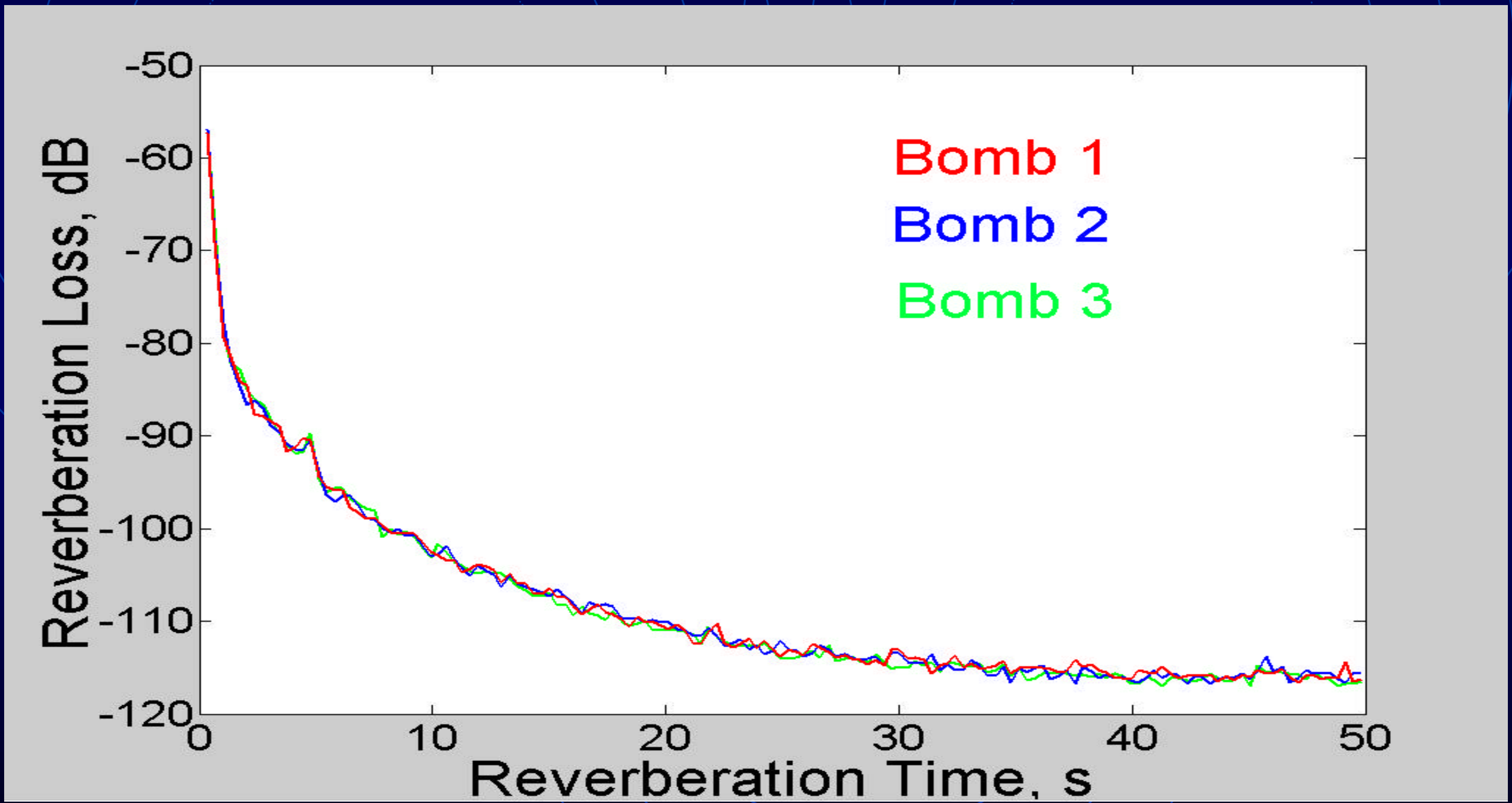
$(t=t0 \text{ to } t0+dt)$

Reverberation loss $RL(t)=10*\log10(I(t))-SL$

Reverberation loss vs. time (Bomb 1)



Reverberation loss vs. time (Bomb 1/2/3, Frequency 1kHz)



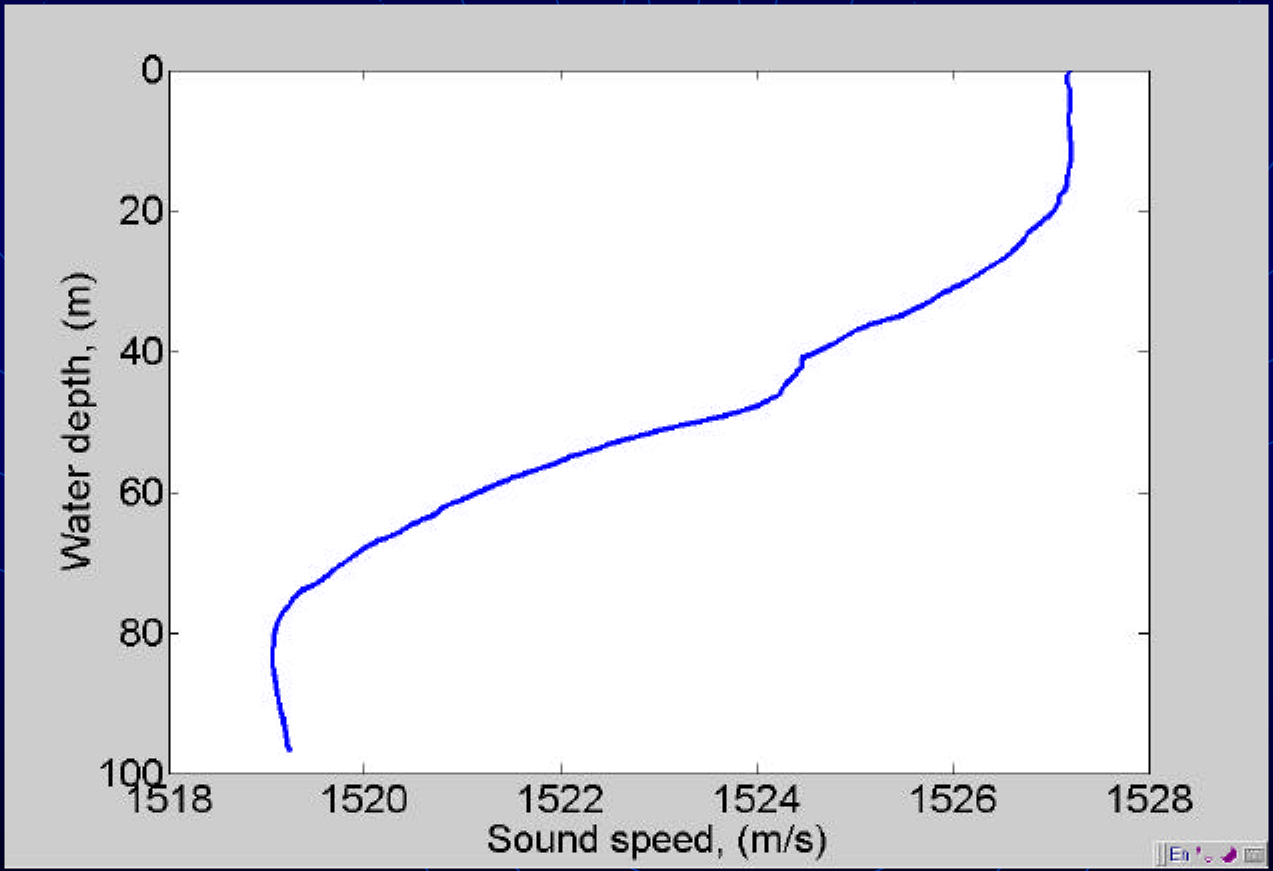
Model/data comparison procession (mathematically)

Have several different expressions of bottom scattering coefficient

Put those expressions into Reverberation model to get numerical results

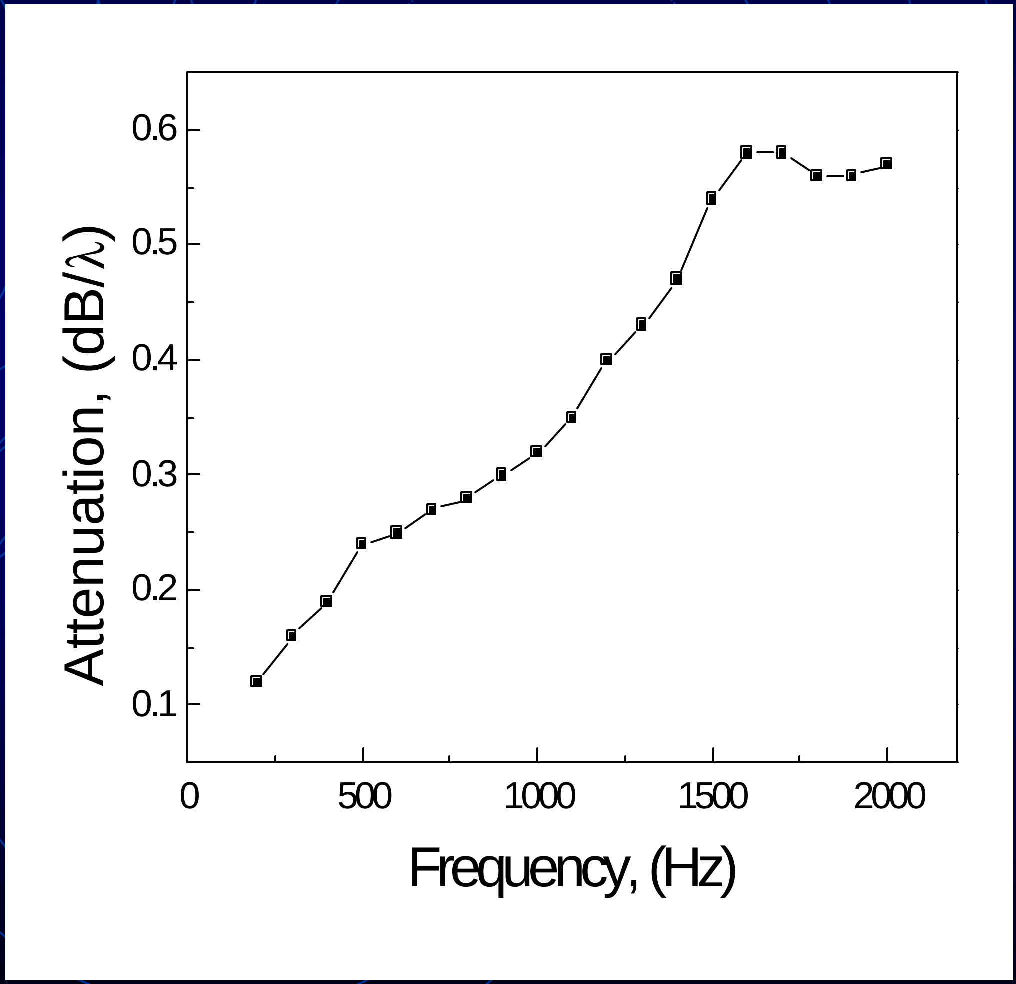
Compare the numerical results with the experimental data to find out the best expression for this experiment

Sound Speed Profile

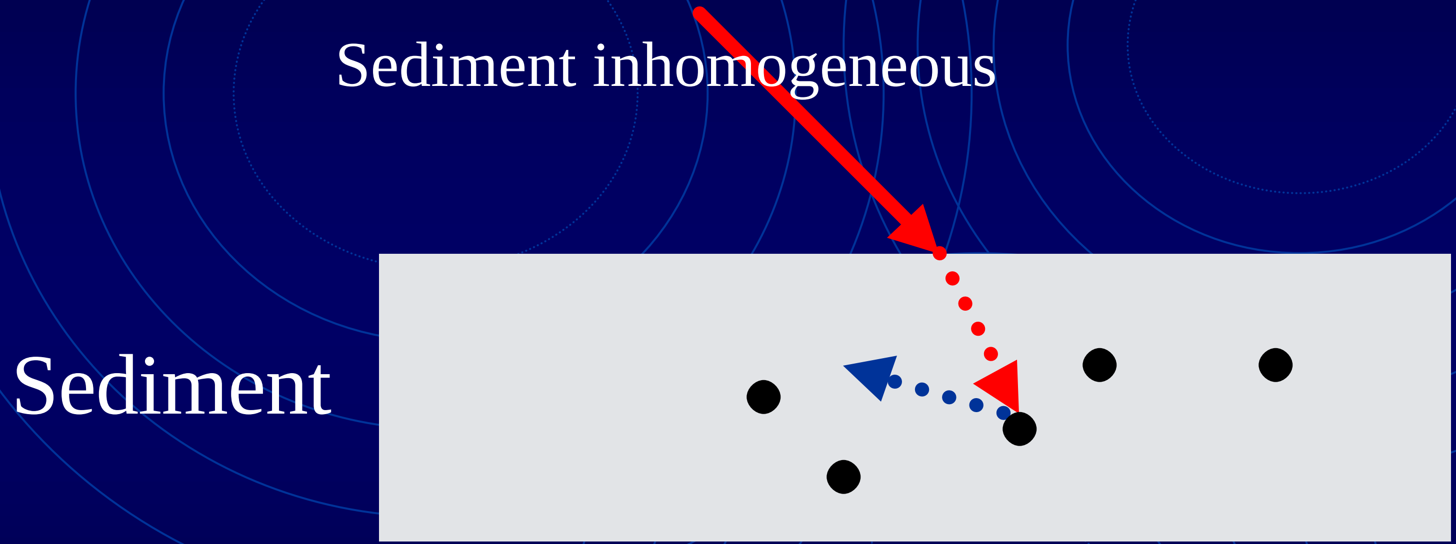


Bottom parameters

- Bottom speed, 1610.8m/s
- Bottom density 1.86g/cm^3
- From Geoacoustic Inversion by Dr. Zhenlin Li



The discrete sediment inhomogeneous scattering model



- For signal scatterer , $s \propto k^4$
- Neglect multiple scattering,

$$s\left(q_i, q_s\right) = B_L k_2^{\,3} \left|1 + R_{1-2}\left(q_i\right)\right|^2 \left|1 + R_{1-2}\left(q_s\right)\right|^2 \frac{1}{2\left[\operatorname{Im}\sqrt{\left(\left(\frac{k}{k}\right)^2 - \cos^2 q_i\right)} + \operatorname{Im}\sqrt{\left(\left(\frac{k}{k}\right)^2 - \cos^2 q_s\right)}\right]}$$

- The above expression approximates to the sediment inhomogeneous model from Jackson, etc. $W(k) \propto 1/k^0$

- The above expression also approximates perturbation l $W(k) \propto 1/k^1$ ghness model from Jackson, etc.

Published mathematical expressions of bottom scattering coefficient (incomplete)

1 $$s(q_i, q_s) = m \sin(q_i)\sin(q_s)$$

2 $$s(q_i, q_s) = m \sin^{1/2}(q_i)\sin^{1/2}(q_s)$$

3 $$s(q_s, q_i) = m \sin^{l}\left(\frac{q_i + q_s}{2}\right)$$

4 $$s = m\left[\frac{\sin(q_i)\sin(q_s)}{(\sin(q_i) + \sin(q_s))}\right]^{l}$$

5 $$s(q_s, q_i) = m \sin^{l}\left(\cos^{-1}\left(\frac{\cos(q_i) + \cos(q_s)}{2}\right)\right)$$

6 $$s(q_i, q_s) \approx \frac{1}{4p} a\left(\frac{\sin(q_i) + \sin(q_s)}{2} k\right)^{2}$$

7 $$s(q_i, q_s) = B_L k_2{}^{3} \left|1 + R_{1-2}(q_i)\right|^{2} \left|1 + R_{1-2}(q_s)\right|^{2} \frac{1}{2\left[\operatorname{Im}\sqrt{\left(\left(\frac{k}{k}\right)^{2} - \cos^{2} q_i\right)} + \operatorname{Im}\sqrt{\left(\left(\frac{k}{k}\right)^{2} - \cos^{2} q_s\right)}\right]}$$

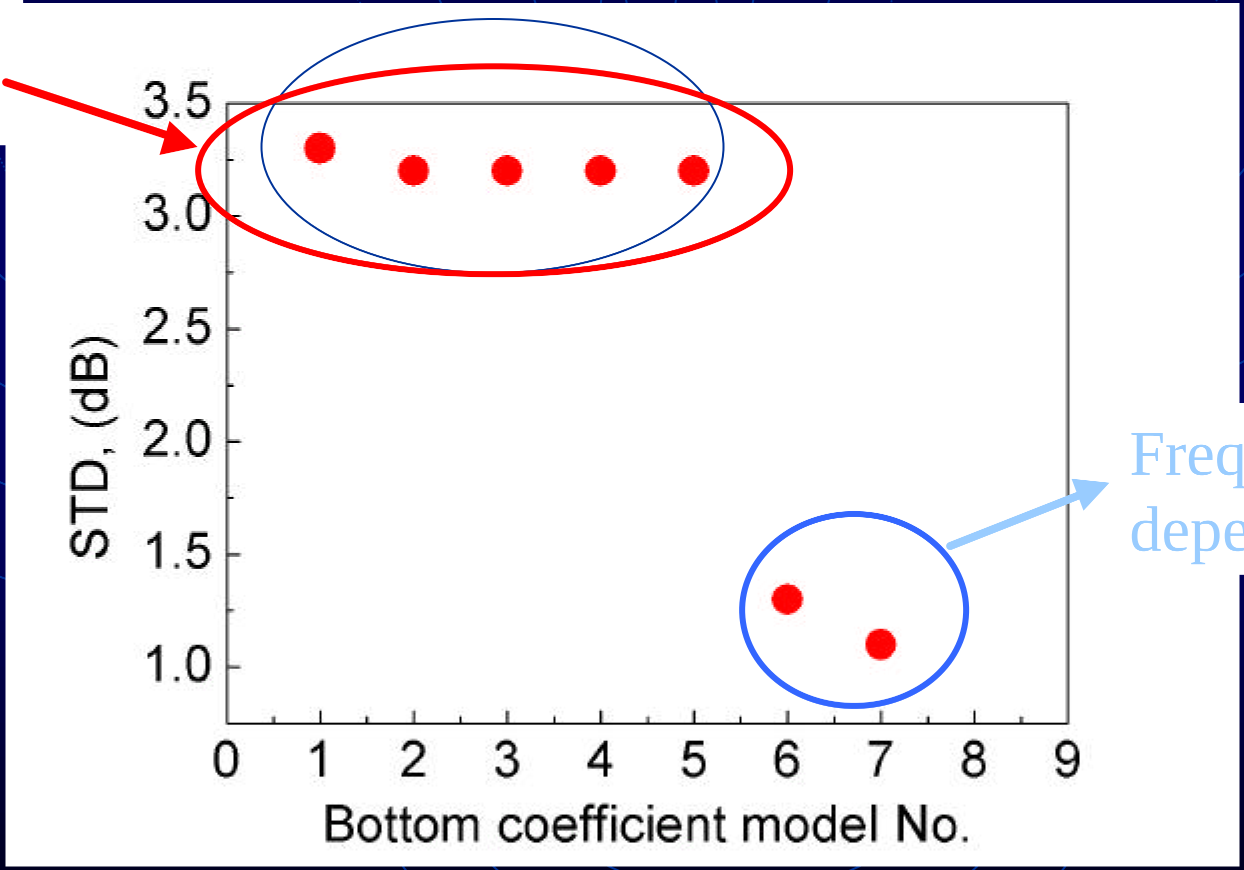
The criterion for Model/data comparison

- Minimum Standard Deviation criterion

$$Min(SD)=Min(sqrt(sum(RL_e(t_i)-RL_n(t_i))^2/N)))$$

Standard Derivations for different expressions (2-15s, 700 to 2kHz)

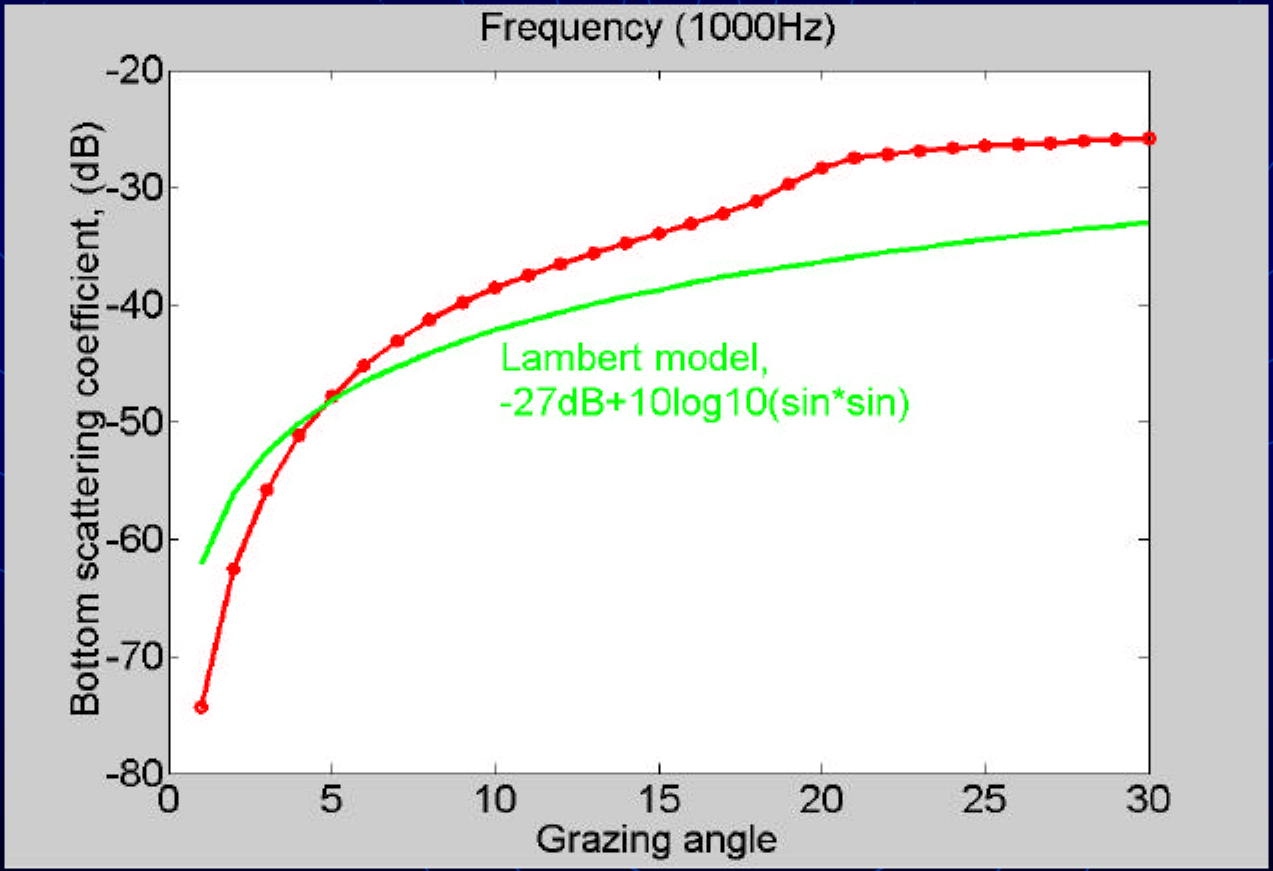
Frequency independent



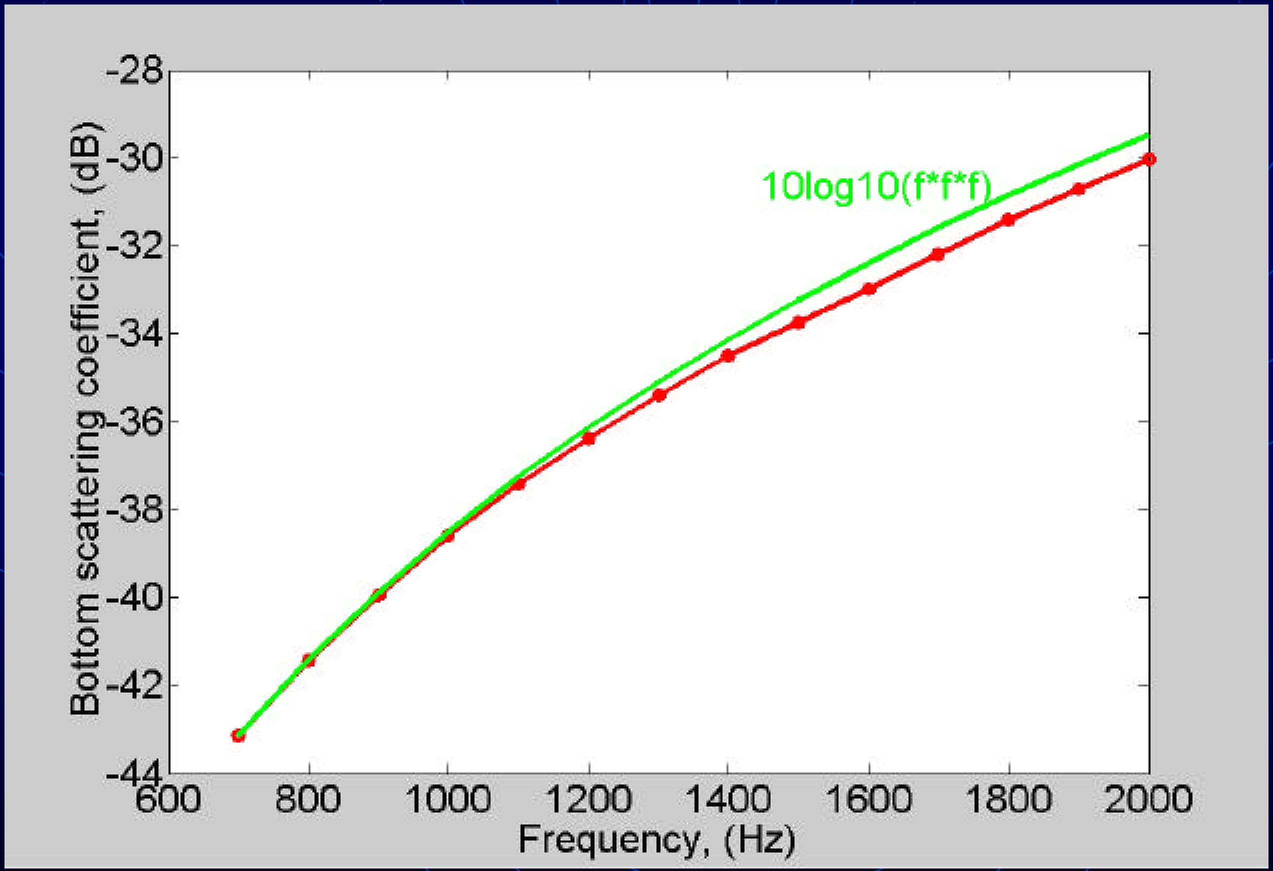
Frequency dependent

- The bottom scattering coefficient has a strong frequency relationship.
- For explaining 700Hz to 2000Hz experimental RL data, the discrete sediment inhomogeneous model is best model among the models shown in this paper.

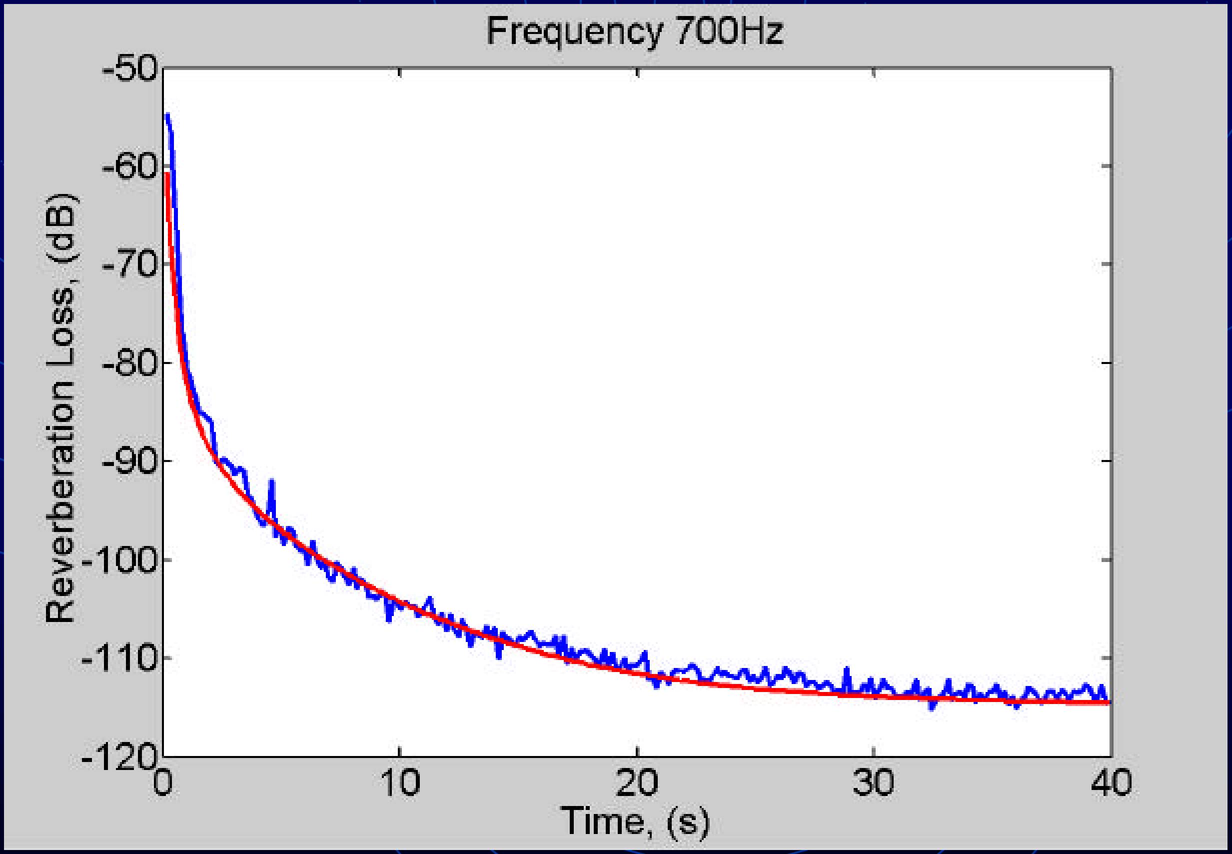
The bottom scattering coefficient



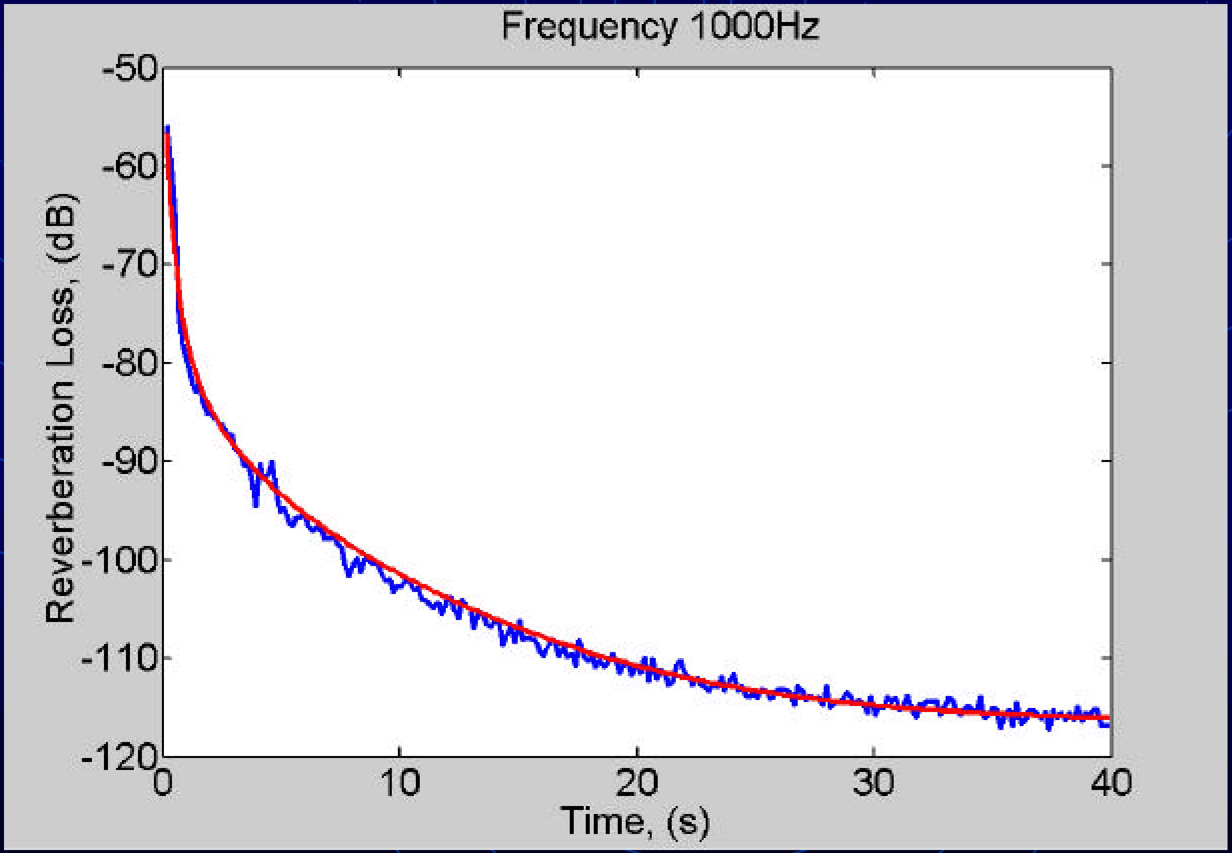
The bottom scattering coefficient (Grazing angle is 10degree)



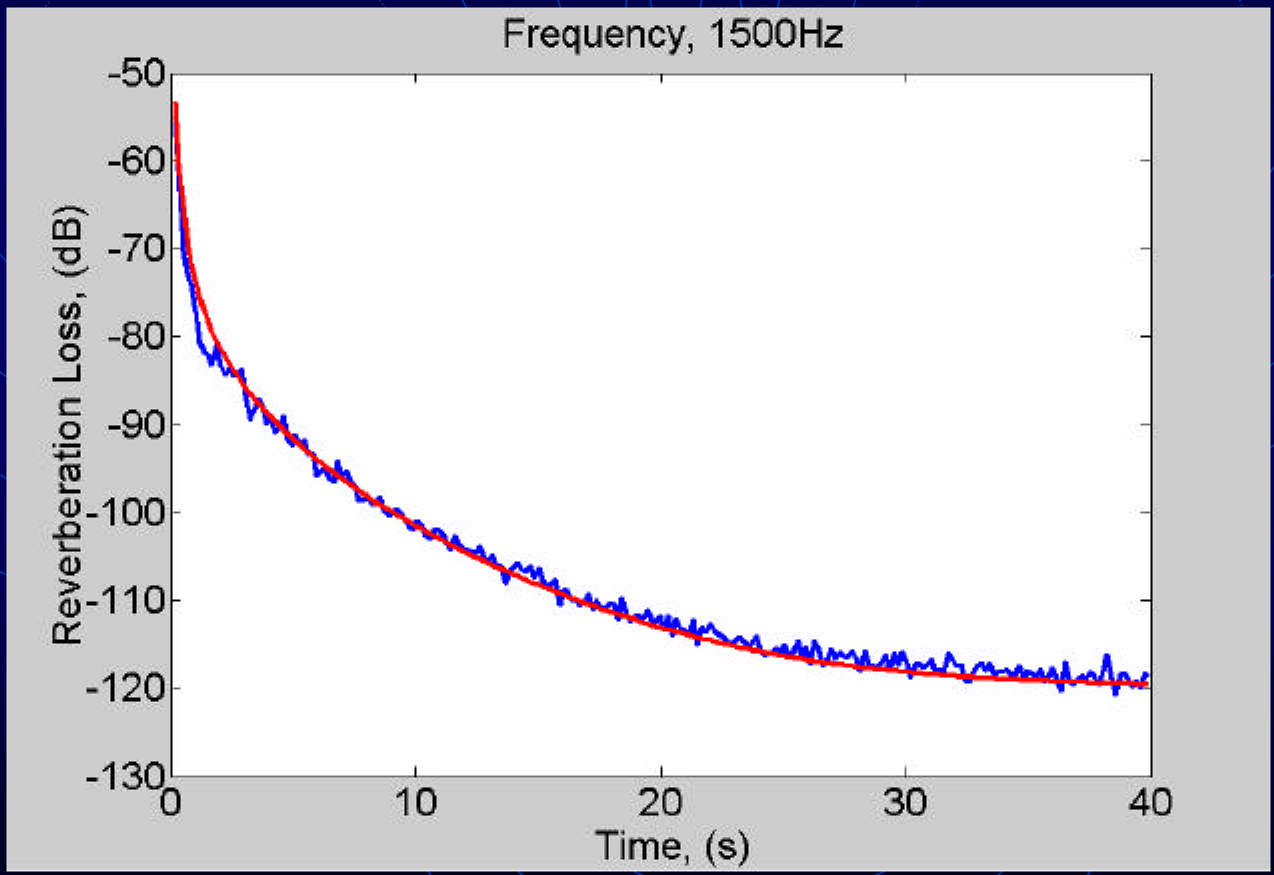
Model/data comparison (700Hz)



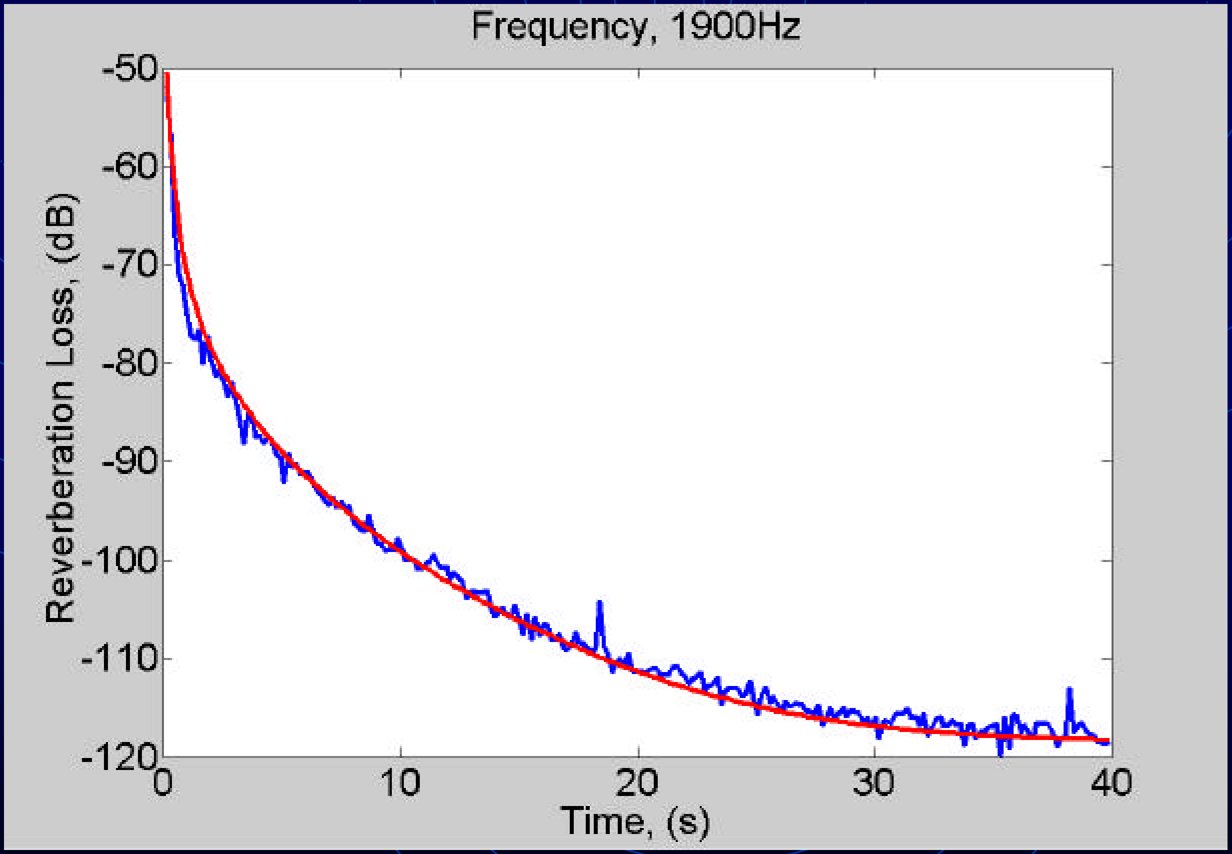
Model/data comparison (1000Hz)



Model/data comparison (1500Hz)

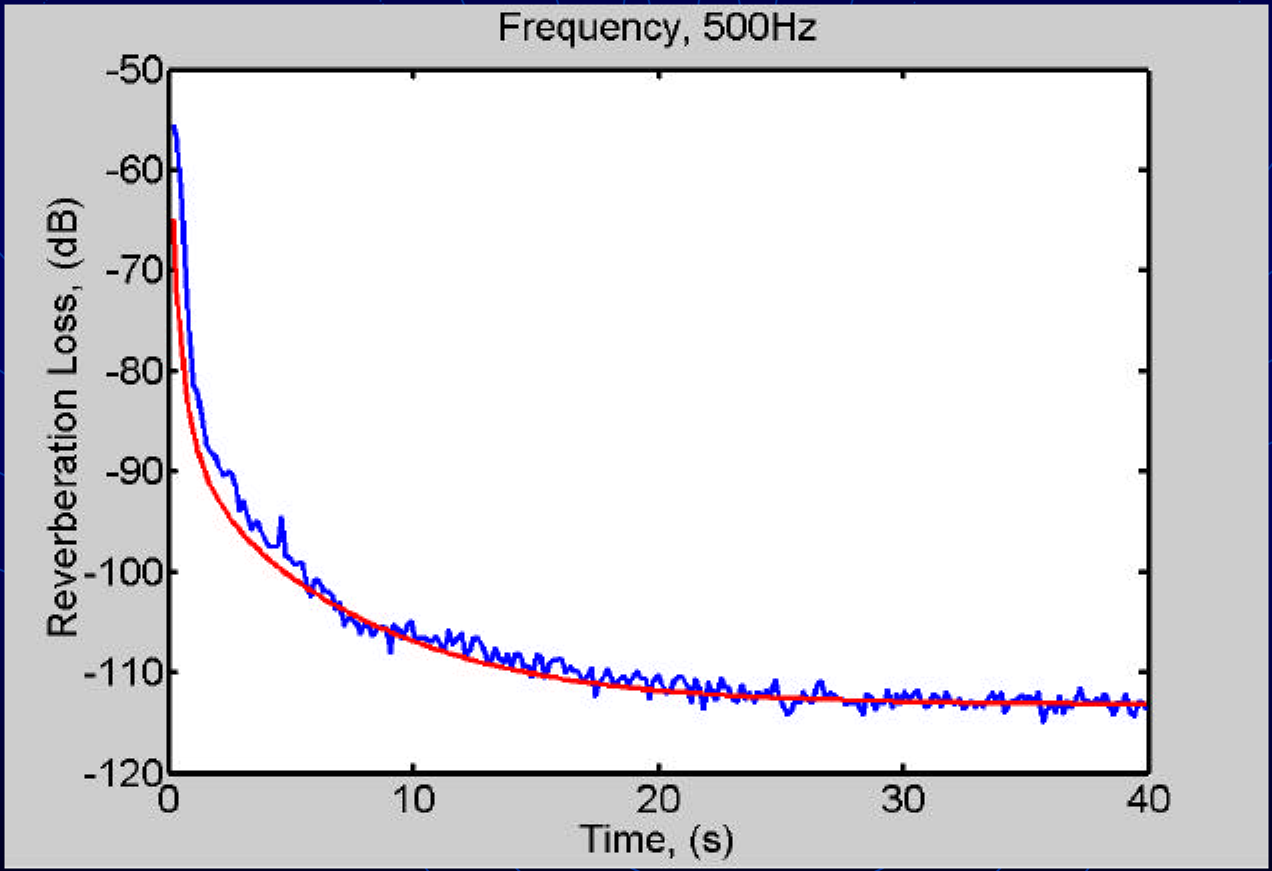


Model/data comparison (1900Hz)

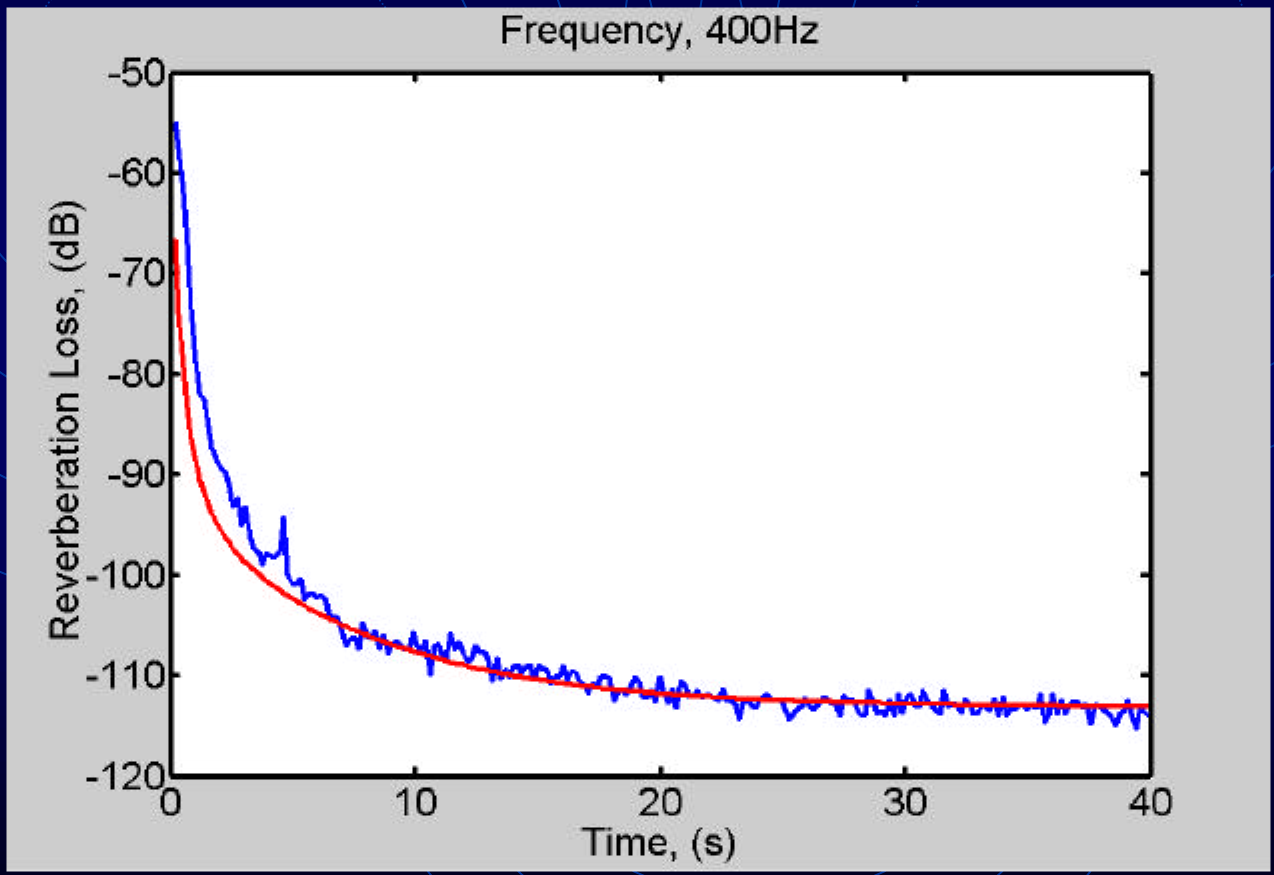


2. Low Frequency reverberation data

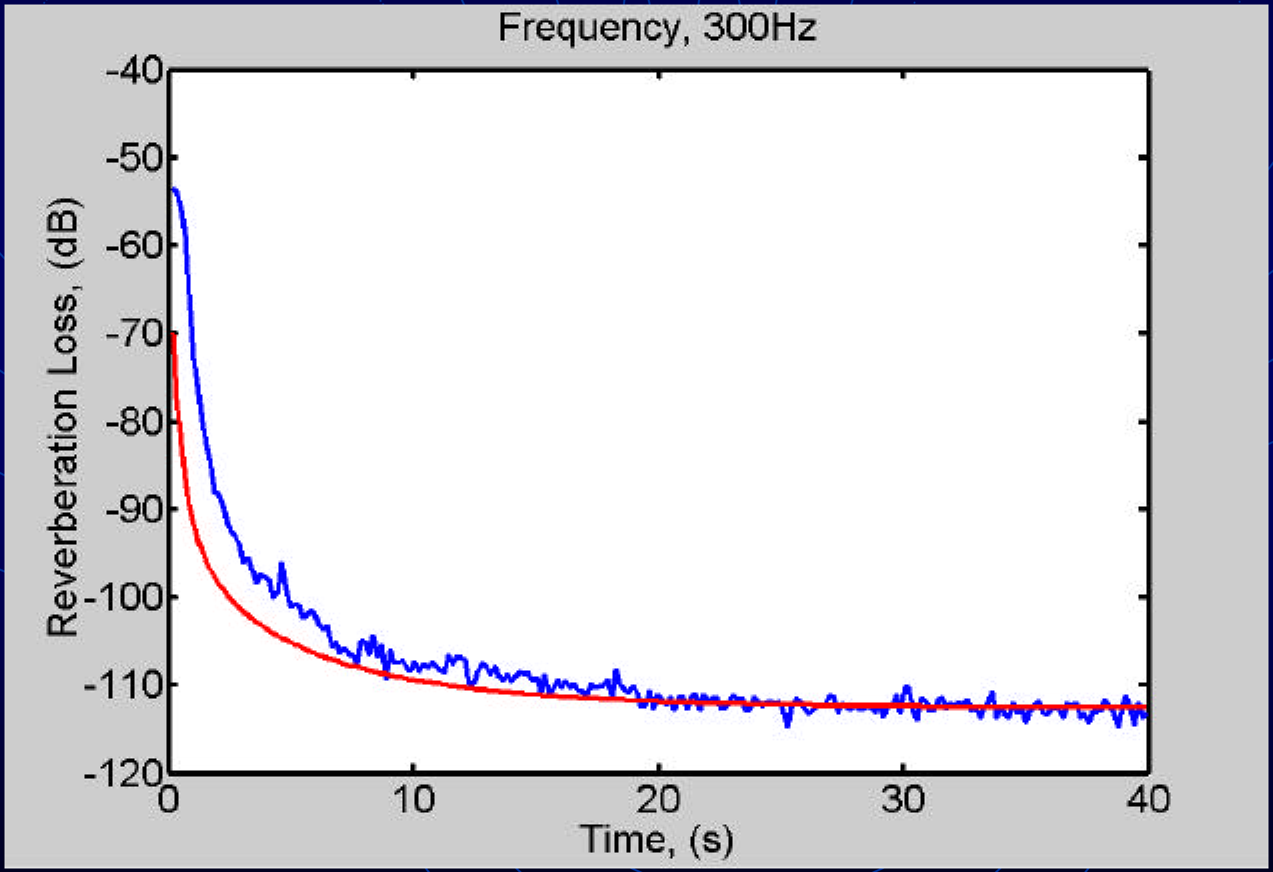
Model/data comparison (500Hz)



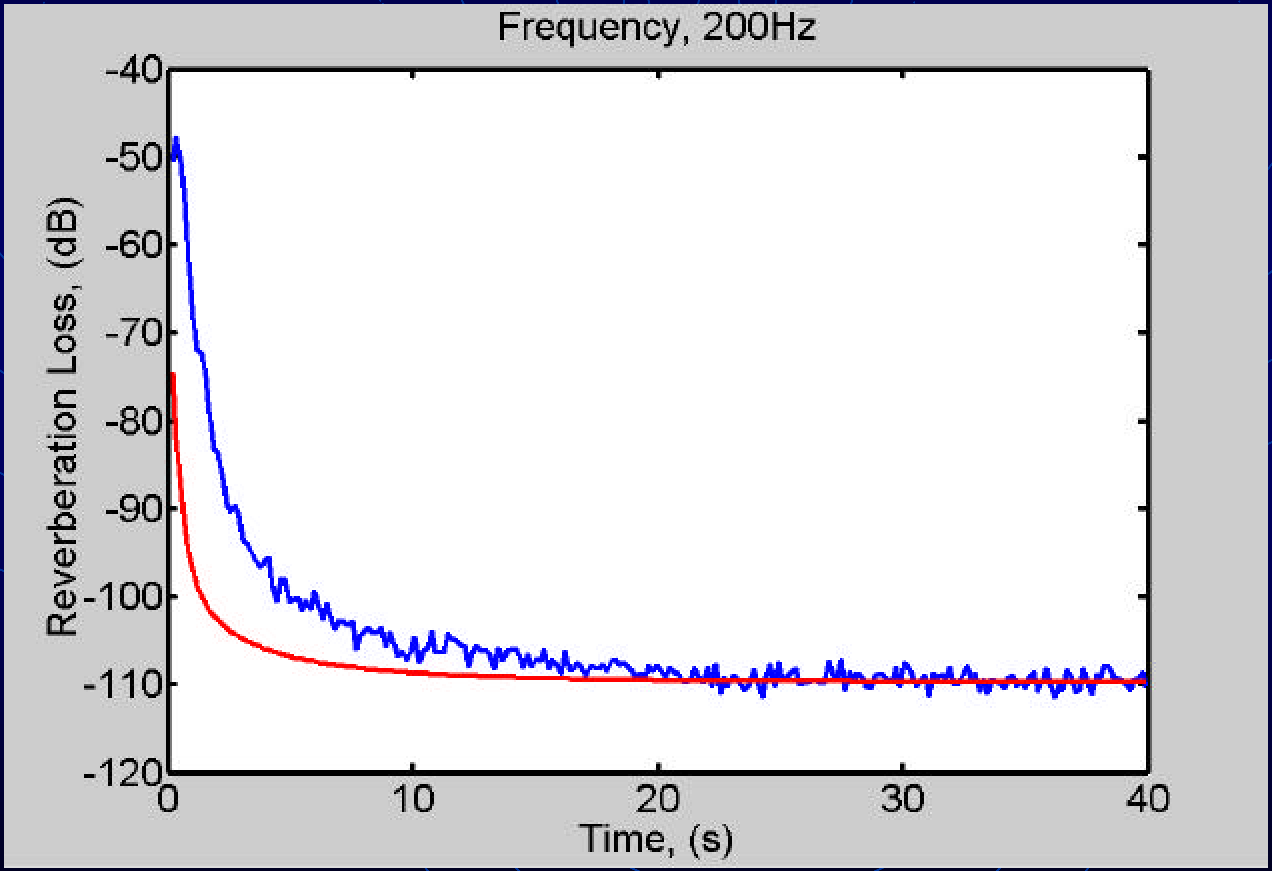
Model/data comparison (400Hz)



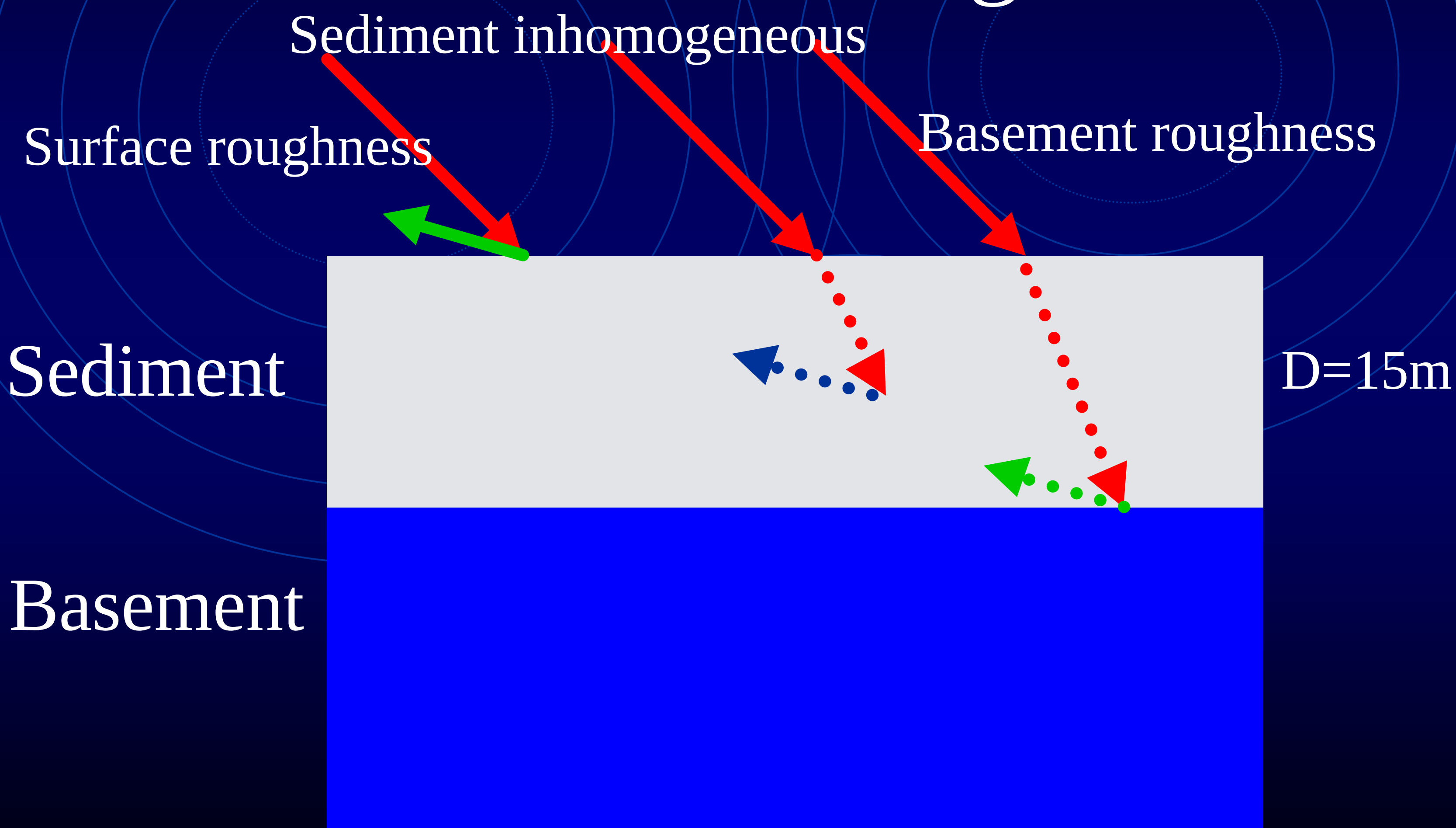
Model/data comparison (300Hz)



Model/data comparison (200Hz)



The sediment-basement combined scattering model



The sediment-basement combined scattering model

- Bottom scattering includes the scattering from the sediment inhomogeneous and the basement roughness.

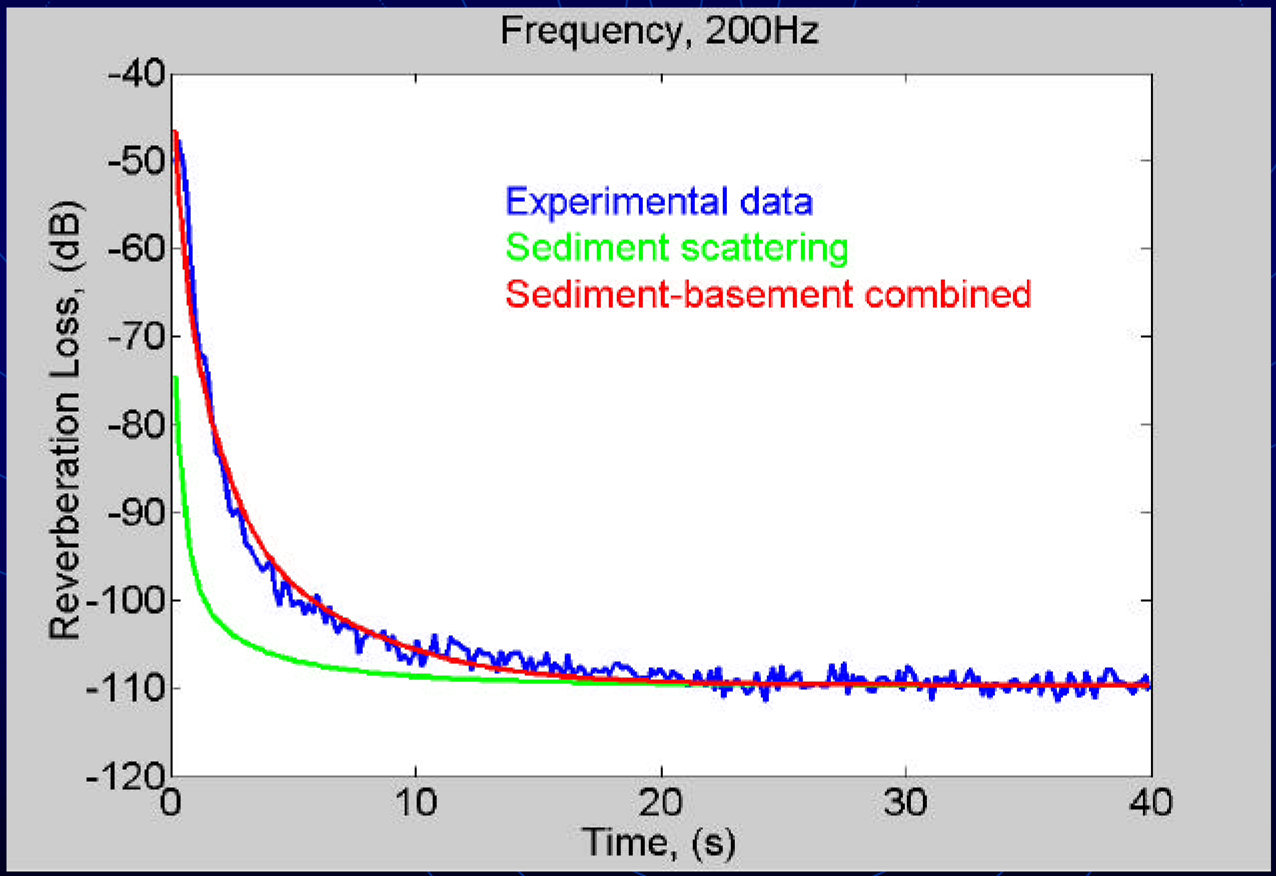
$$s\left(q_i, q_s\right) = B_L k_2^{\;3} \left|1 + R_{1-2}(q_i)\right|^2 \left|1 + R_{1-2}(q_s)\right|^2 \frac{1}{2\left[\operatorname{Im}\sqrt{\left(\left(\frac{k}{k}\right)^2 - \cos^2 q_i\right)} + \operatorname{Im}\sqrt{\left(\left(\frac{k}{k}\right)^2 - \cos^2 q_s\right)}\right]}$$

$$+ B_L \left|1 + R_{1-2}(q_i)\right|^2 \left|1 + R_{1-2}(q_s)\right|^2 \exp(-2gD) W(k) \left|F(k)\right|^2$$

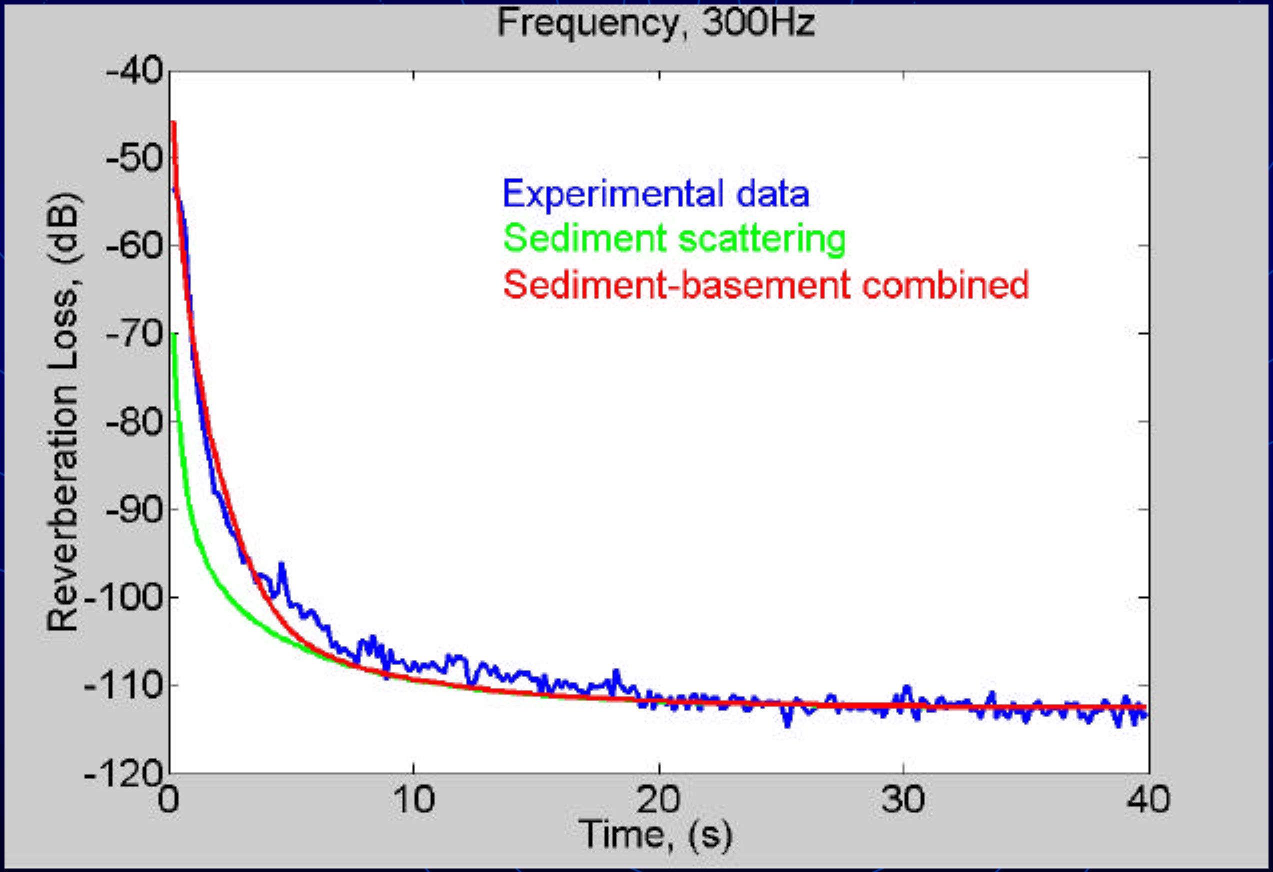
« Ivakin, JASA, 1998, vol. 103»

- D=15m

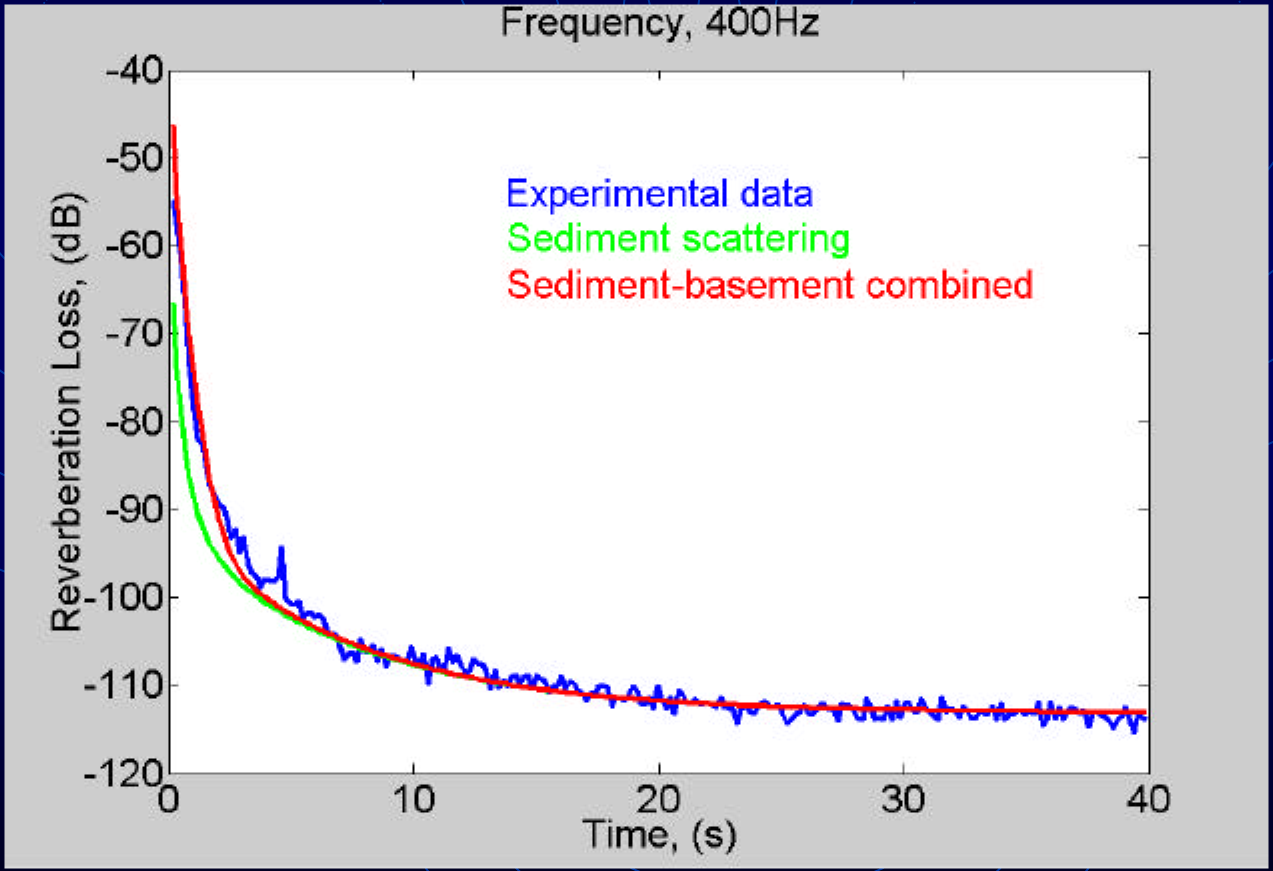
Model/data comparison (200Hz)



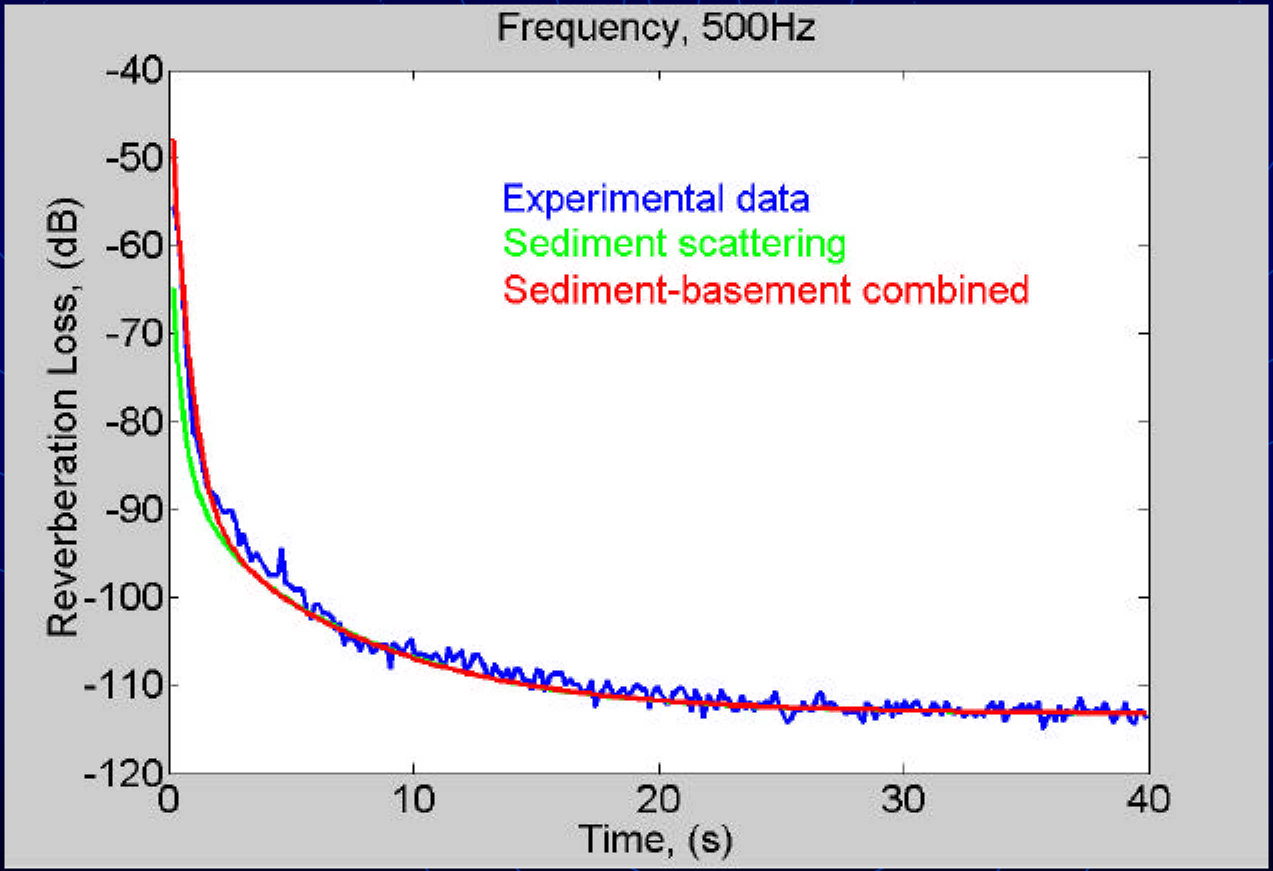
Model/data comparison (300Hz)



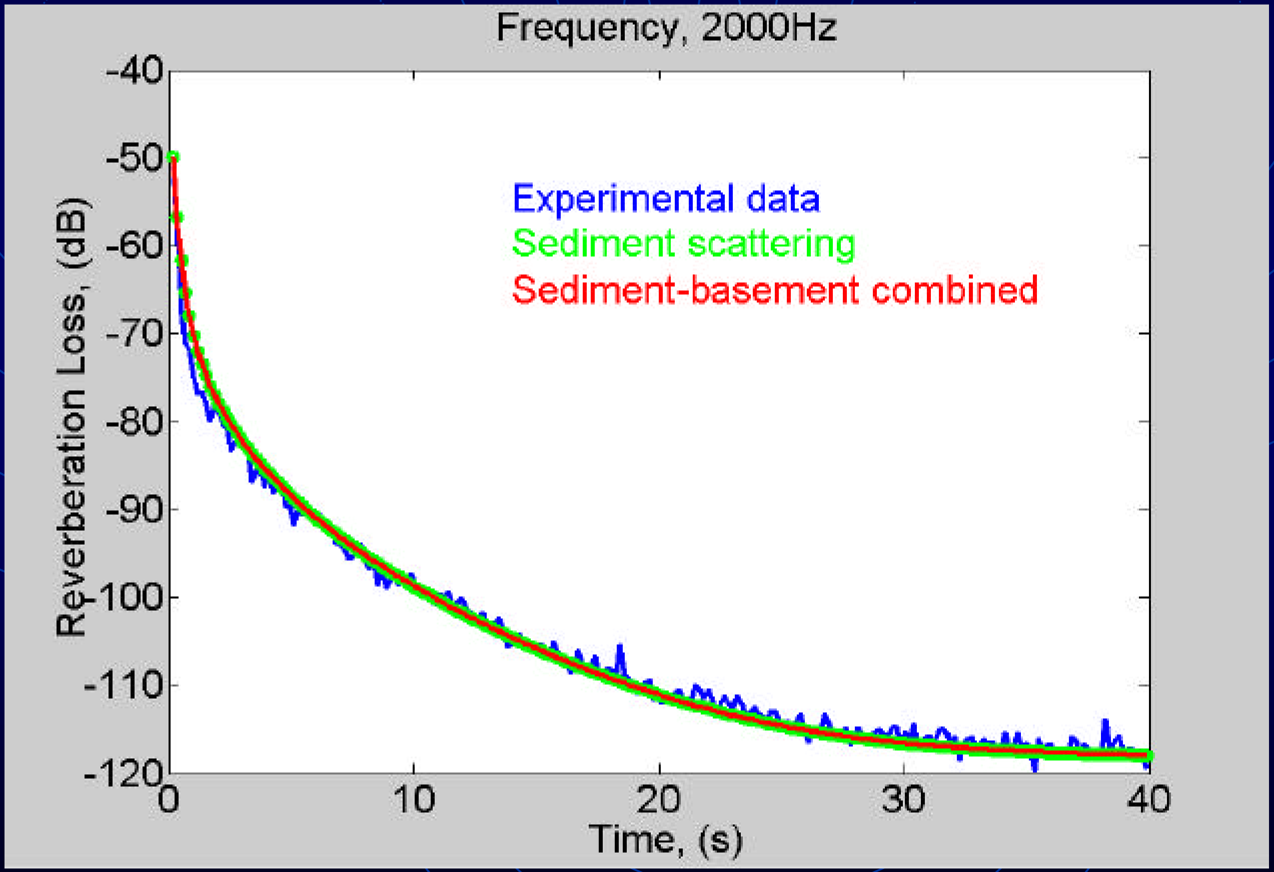
Model/data comparison (400Hz)



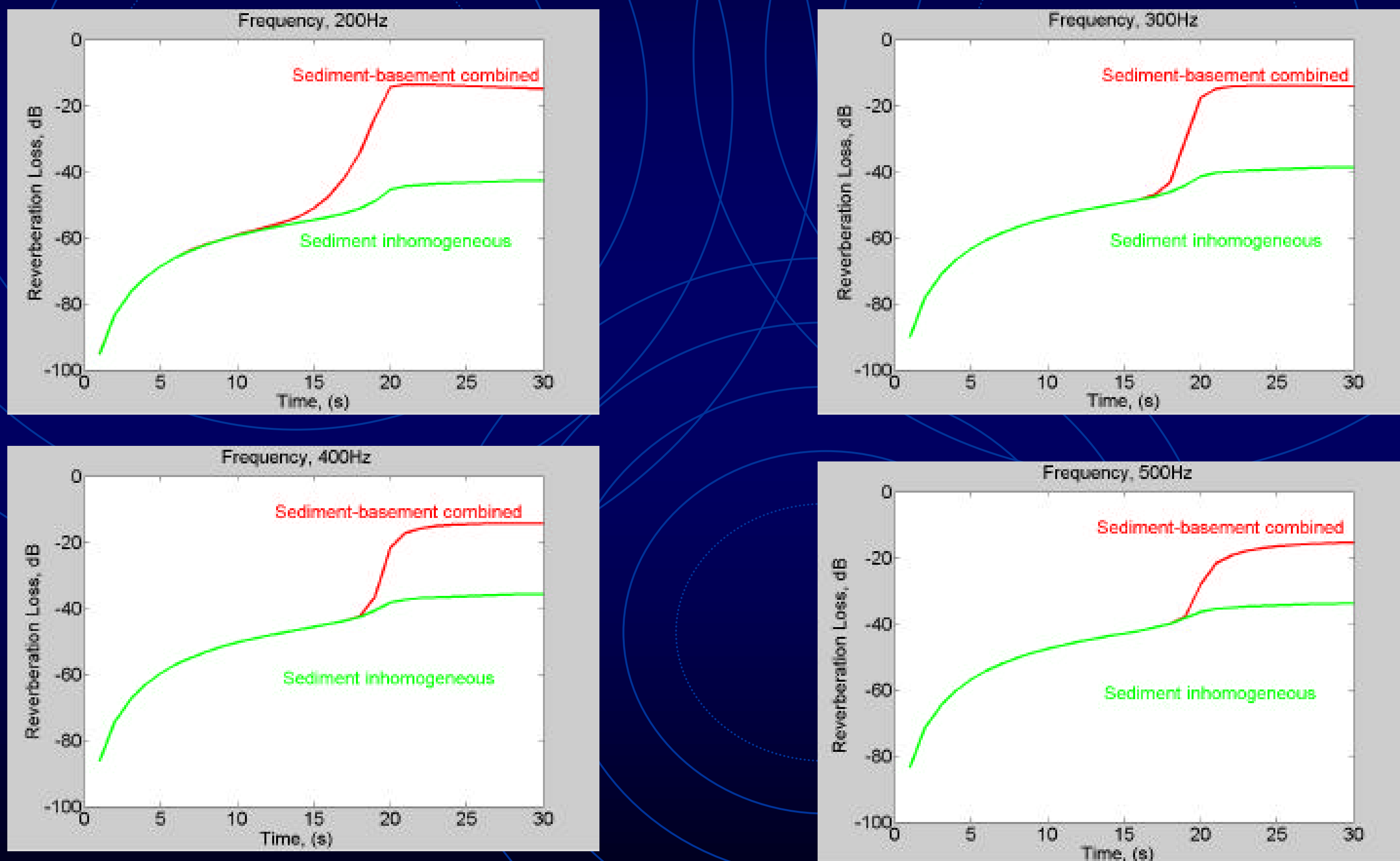
Model/data comparison (500Hz)



Model/data comparison (2000Hz)



Bottom scattering coefficients



Summaries

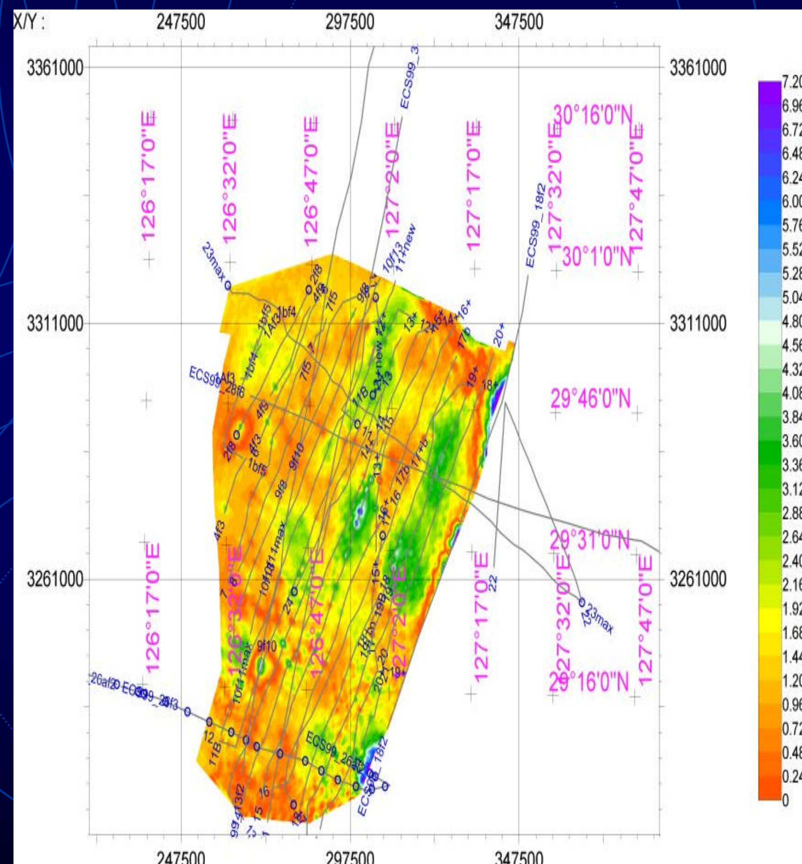
- The bottom scattering coefficient has a strong frequency relationship (f^3).
- For 700Hz to 2000Hz experimental RL data, the discrete sediment inhomogeneous model is best model among the models shown in this paper.
- The scattering from deeper layer may be a dominating effect for low frequency reverberation data.

Other open problems!

- Can this model predict the reverberation correlation?
- How to distinguish the sediment inhomogeneous and surface roughness
- The multiple scattering effect?
- Comparison with the other scattering data?

Other open problems!

- Geoacoustic model
  - Basement is not rigid?
  - Sound speed has a positive gradient in the sediment?
  - There is a scattering layer at about 15m?



Seafloor to TST isopach or layer thickness of the top layer of sand-silt in meters. (from L. Bartek)

Thanks